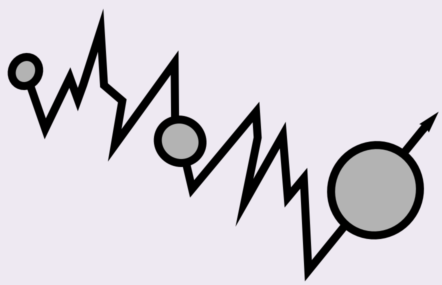
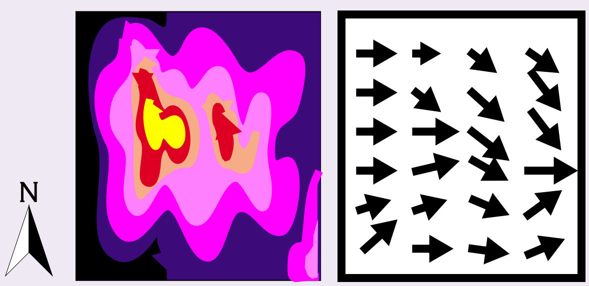
RAPTAD Dispersion Module

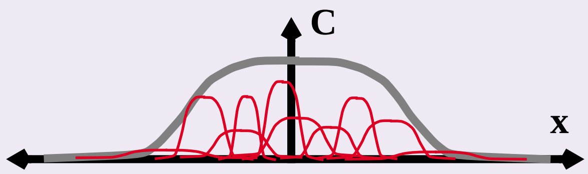


pollutant parcels transported using random-walk eqn.

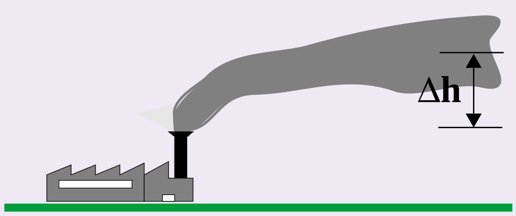
parcels expand as fn. of time, stratification and turbulence intensity



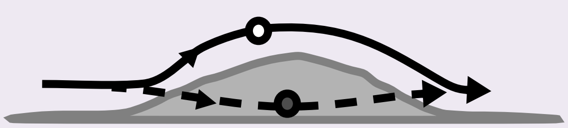
HOTMAC provides mean & turbulent input fields



conc.’s computed from sum of many parcel conc. profiles



accounts for plume rise & point, line, and area sources



accounts for complex terrain, stratification, and inversions

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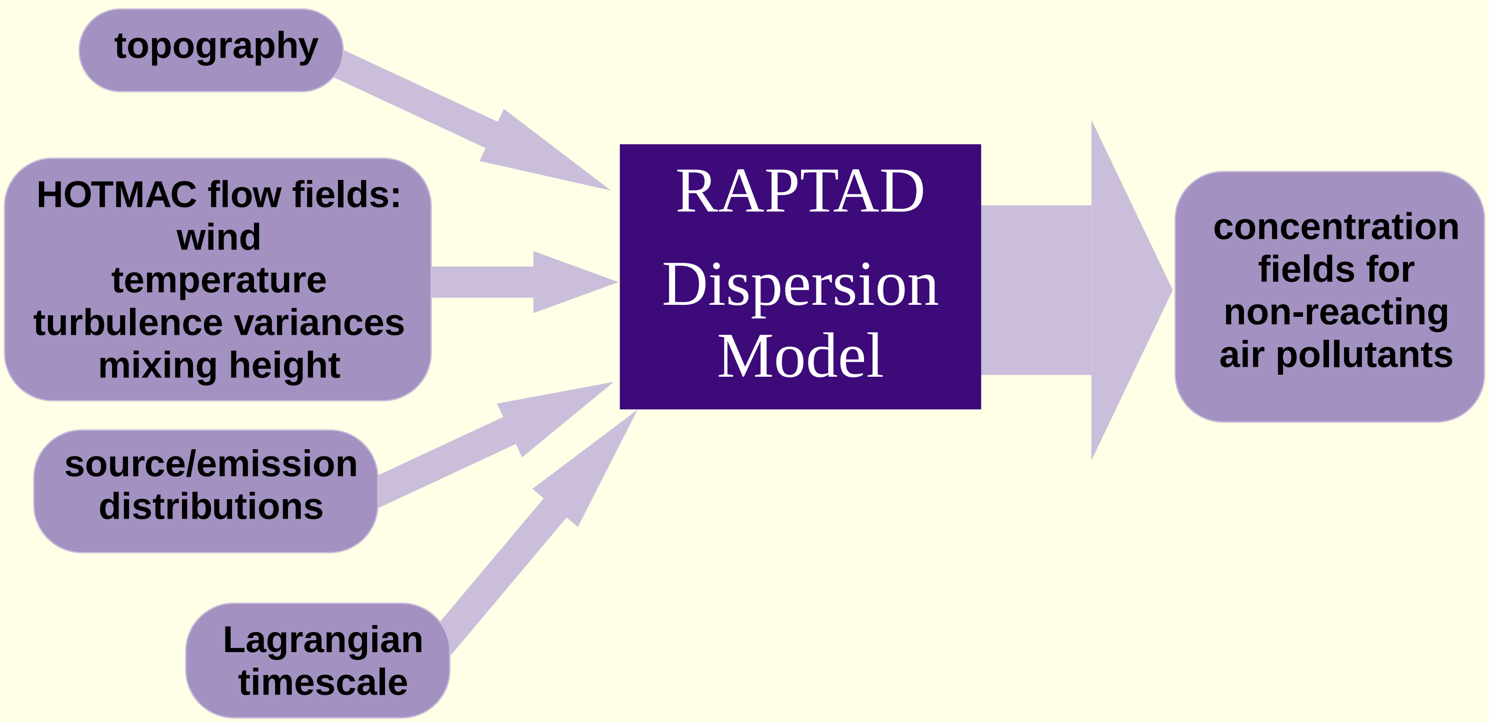
TRANSIMS

Input & Output for the RAPTAD Model

RAPTAD



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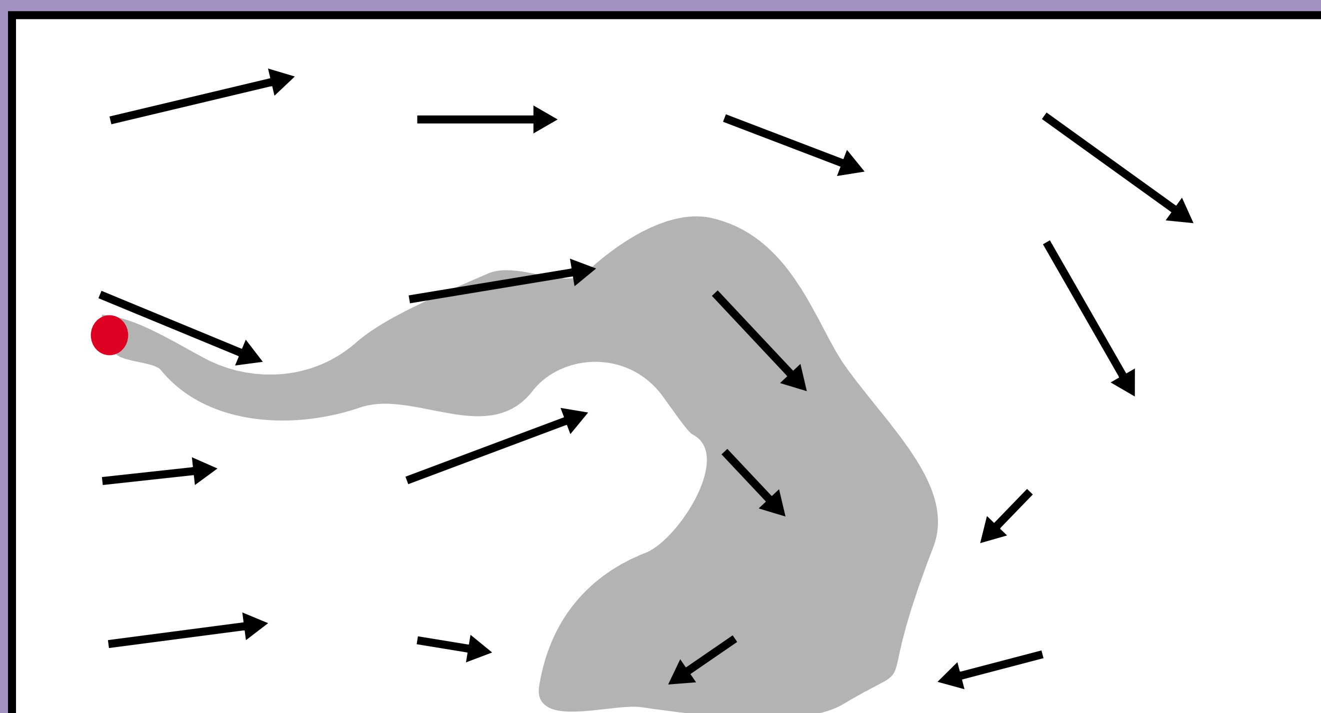
The meteorological model output is input to the dispersion model

meteorological model → wind, temperature, & turbulence fields → dispersion model



The Markov-Chain Random-Walk Equation

$$u_i'(t + \Delta t) = x \cdot u_i'(t) + \Omega$$

Ω and x are determined from homogeneous turbulence relations:

- ☛ variance of Eulerian and Lagrangian velocity fluctuations are equal
- ☛ definition of autocorrelation
- ☛ Taylor’s statistical theory of dispersion

RAPTAD

Reynolds Decomposition of Turbulent Velocity

$$U(t) = \overline{U} + u'(t)$$

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The Monte-Carlo Random-Walk Equation

$$u_i'(t + \Delta t) = \exp(-\Delta t / T_L) \cdot u_i'(t) + \{1 - \exp(-2\Delta t / T_L)\} \cdot \sigma_u \cdot \varsigma$$

where T_L is the Lagrangian timescale,

σ_u is the standard deviation of the velocity fluctuations, and

ζ is a random variable chosen from a normal distribution with zero mean and standard deviation of one.

RAPTAD

The Puff Concentration Equation

$$\bar{C}(x, y, z, t) = \frac{Qt}{\sigma_x \sigma_y \sigma_z (2\pi)^{3/2}} \cdot \exp\left(\frac{(x - x_{cm})^2}{2\sigma_x^2}\right) \cdot \exp\left(\frac{(y - y_{cm})^2}{2\sigma_y^2}\right)$$

$$\cdot \exp\left(\frac{(z - z_{cm})^2}{2\sigma_z^2}\right) \cdot \exp\left(\frac{(z + z_{cm})^2}{2\sigma_z^2}\right)$$

where Q is the source strength (mass/time),

σ is the standard deviation of the concentration distribution, and

(x_{cm}, y_{cm}, z_{cm}) is the location of the puff center-of-mass.

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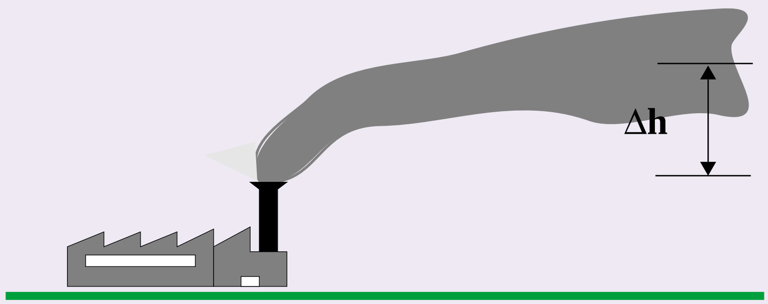
Plume Rise and Buoyant Mixing



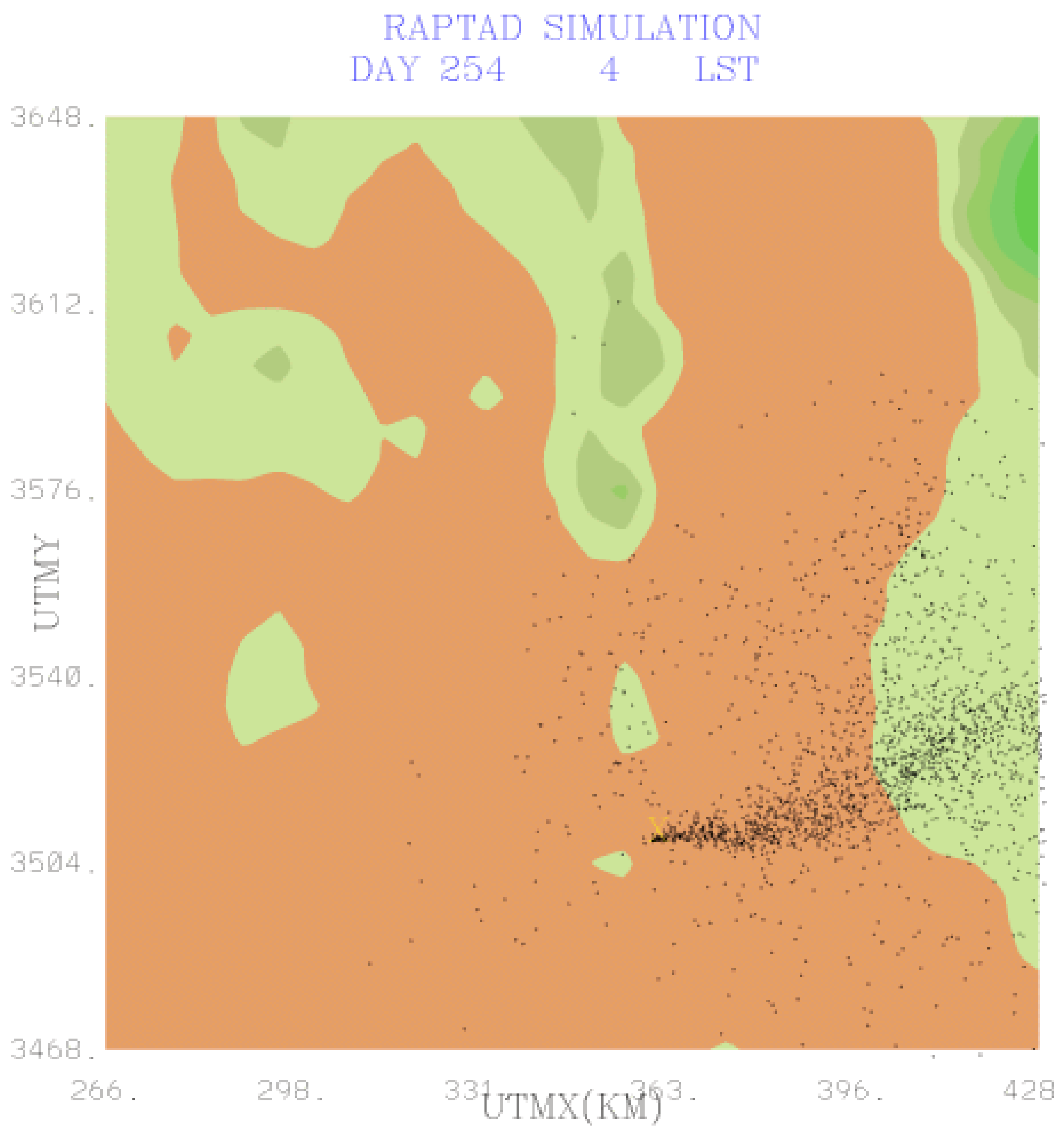
From **dimensional analysis** and **empirical data**, plume rise formulae are obtained, e.g.,

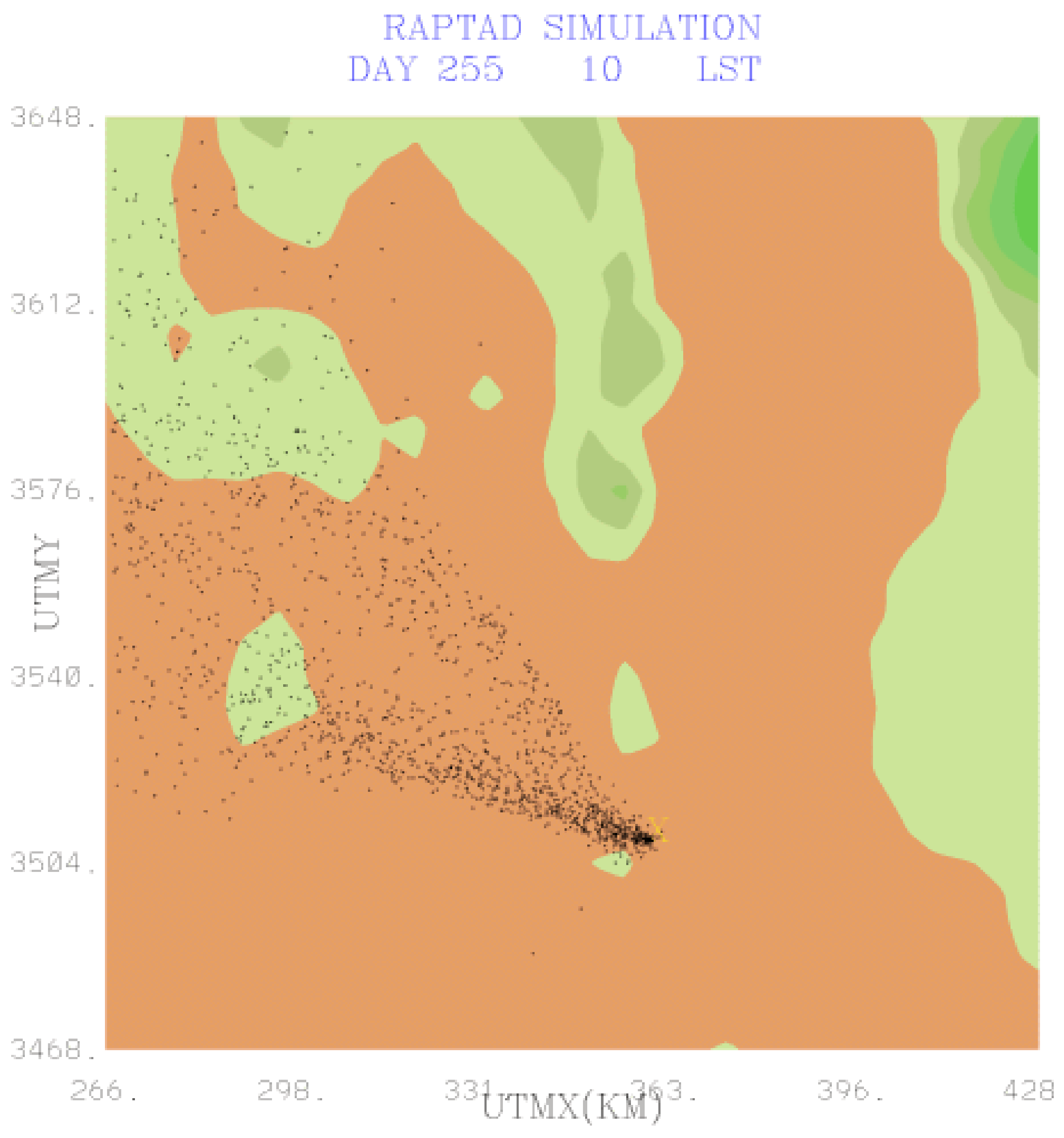
$$\Delta h = c\, F_b^{1/3}\, x^{2/3}\, U^{-1}$$

note: modifications are made to account for stability, inversions, and calm winds

From **empirical data**, a formula for near-source buoyant plume mixing is obtained,

$$\sigma_z = \Delta h/3.5$$


RAPTAD SIMULATION
DAY 254 4 LST
3648.
3612.
3576.
3540.
3504.
3468.
UTMY
266.
298.
331.
363.
396.
428.
UTMX(KM)


RAPTAD SIMULATION
DAY 255 10 LST
3648.
3612.
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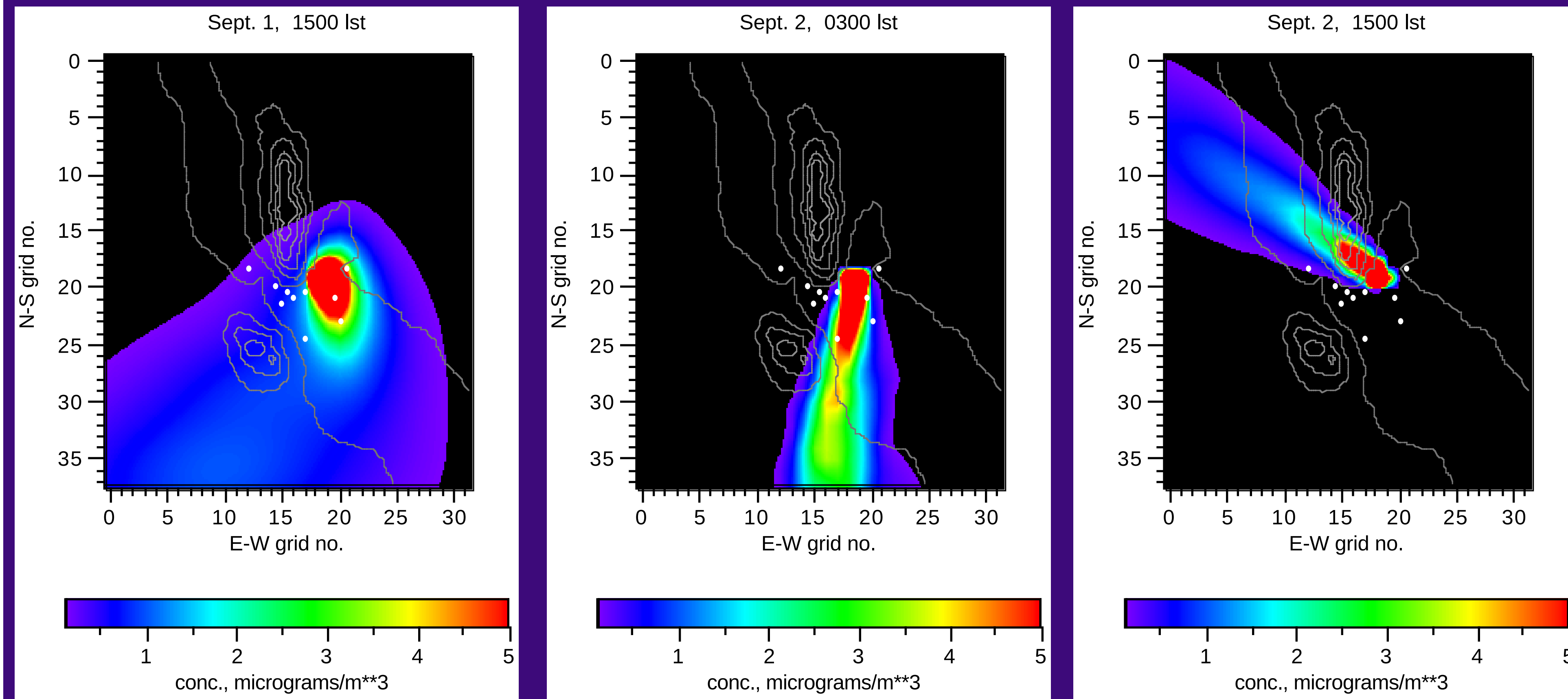
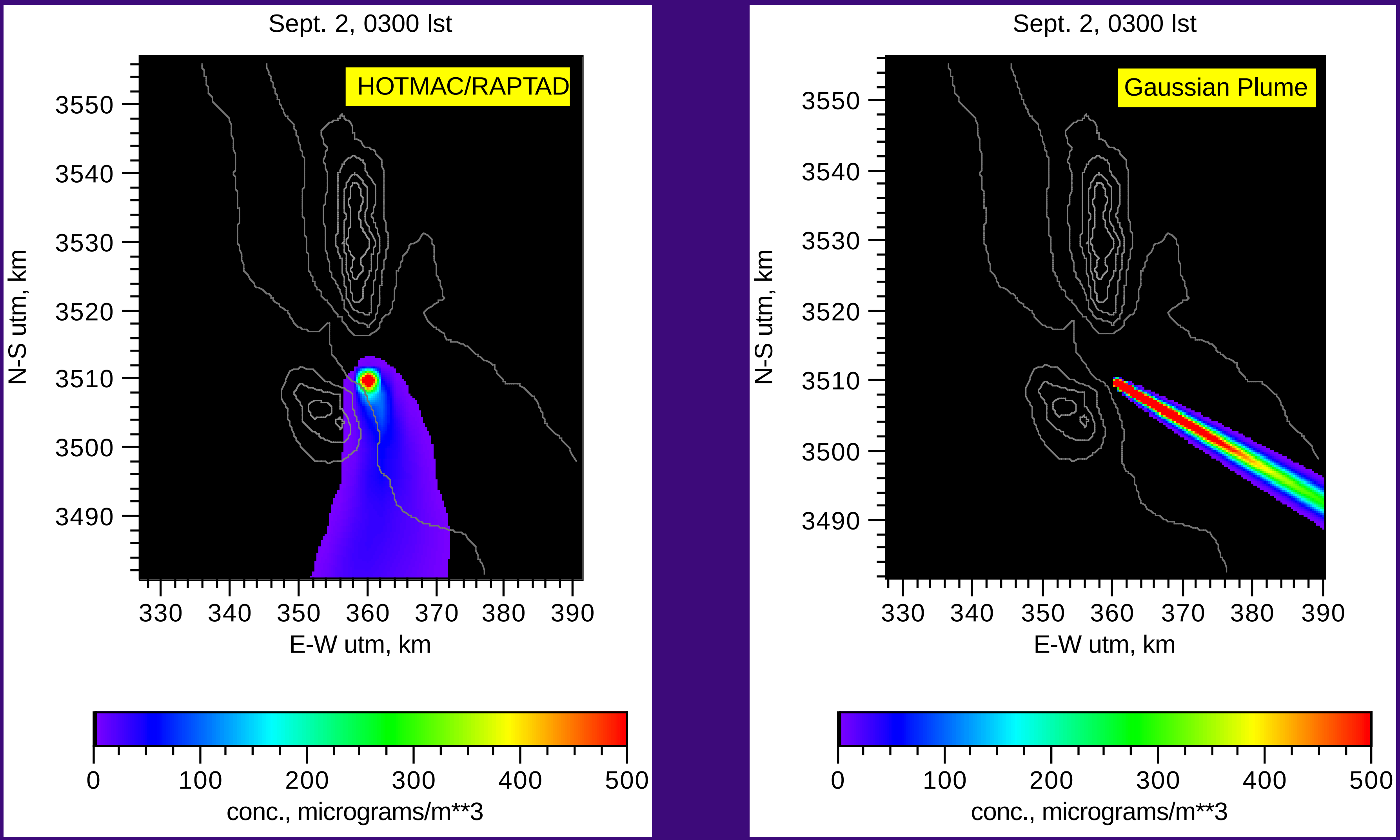
UTMX(KM)

Plume Dispersion Modeling in an Urban-Mountainous Setting



Plume dispersion simulation of a 2 km x 2 km ground source located in the El Paso/Ciudad Juarez region. Hourly-averaged surface concentration contours are shown at 12 hour intervals. The meteorological and concentration fields were computed by LANL's HOTMAC-RAPTAD modeling system. Plume concentrations change due to varying wind, temperature, and turbulence fields.



Comparison of ground-level concentrations computed by the HOTMAC/RAPTAD prognostic modeling system and a Gaussian plume model for a small ground-level area source. Differences are primarily caused by the presence of vertical wind shear and relatively strong turbulent mixing in the wake of the mountains predicted by the HOTMAC meteorological model.

Concentration Solution Techniques

$$\frac{\partial}{\partial t}\bar{C} = \overline{U_j}\frac{\partial}{\partial x_j}\bar{C} + \frac{\partial}{\partial x_j}K_{ij}\frac{\partial}{\partial x_i}\bar{C}$$

Eulerian framework

analytic solutions

- computationally fast

- requires many approximations
  - simplified turbulence closure
  - usually steady-state
  - usually flat surface
  - simplified velocity profiles

finite difference methods

- can handle
  - better turbulence closure
  - non steady-state
  - complex terrain
  - realistic velocity profiles
  - area sources

- computationally slow
- numerical diffusion
- pt. source dispersion difficult

RAPTAD

Concentration Solution Techniques

Lagrangian framework

random walk

- can handle
  - better turbulence closure
  - non steady-state
  - complex terrain
  - realistic velocity profiles
  - point sources

- computationally slow
- area source dispersion difficult (need many particles)
- need knowledge of Lagrangian timescale

random-walk/puff

- computationally faster
- can handle
  - better turbulence closure
  - non steady-state
  - complex terrain
  - realistic velocity profiles
  - area and point sources

- need knowledge of Lagrangian timescale

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